Cloud-filtering
and
Residual Cloud Screening

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We discuss methods of cloud-filtering
which takes advantage of the high spectral resolution of AIRS.

We show the effect of using these spectral filters for quality screening of cloud-filtered data

Test developed for strictly cloud-filtered spectra can be applied to :

quality screening cloud-cleared data

screening of cloud-filtered data

single footprint cloud filtering

In order to retrieve minor gases from AIRS data, the spectra have to be essentially free of cloud artifacts.

+0.1K corresponds to about +3 ppm co2 at 2388cm-1, 792 cm-1 and 713cm-1

Cirrus, aerosols and dust produce spectrally correlated effects with magnitude of degrees, which do not average to zero.

These cloud/cirrus/aerosol residuals have to be eliminated at the below 0.1K level by cloud-screening after cloud-clearing or cloud-filtering.

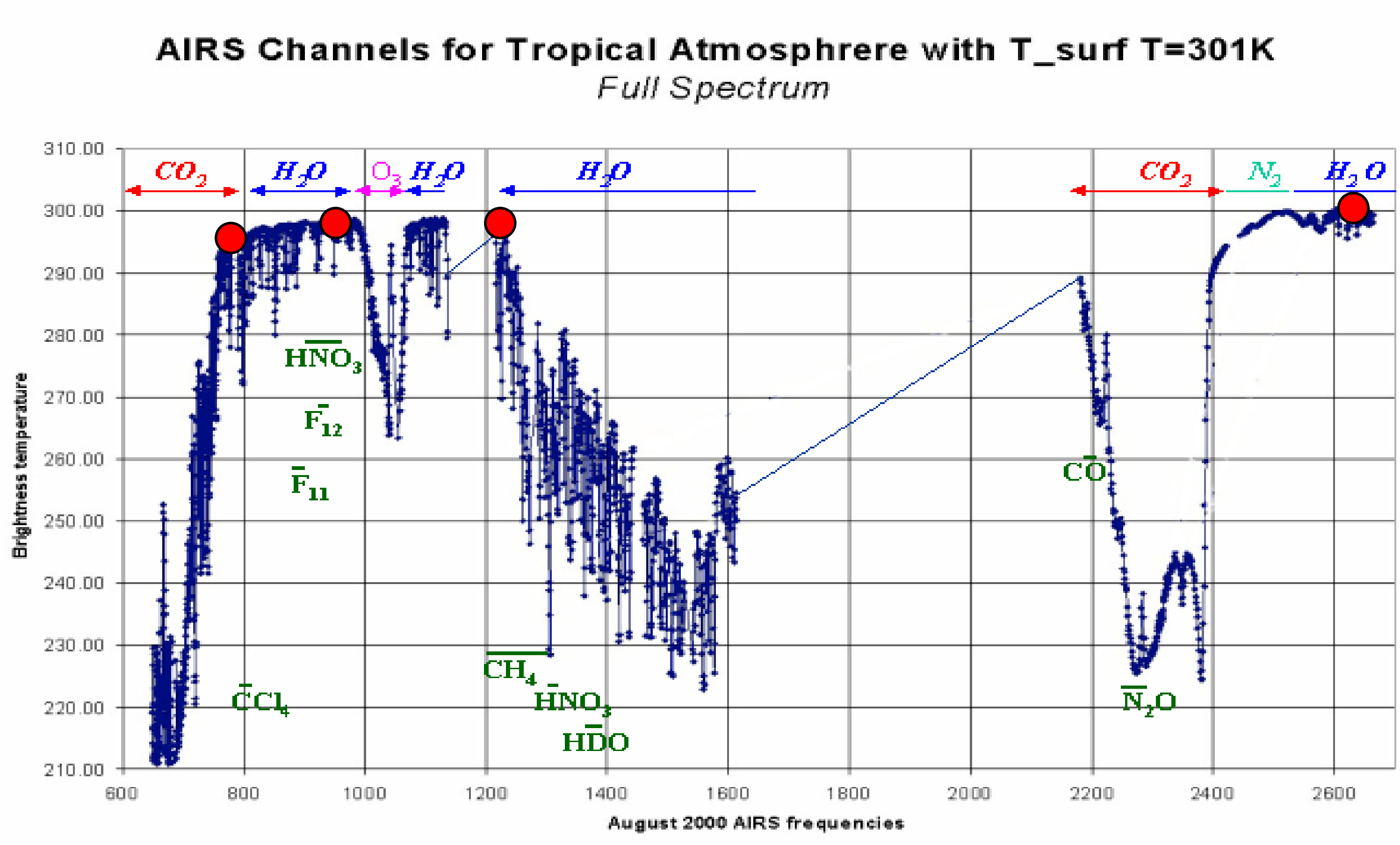
In the following we illustrate the effectiveness of using the hyper-spectral information content of the AIRS data for cloud-contamination screening using roughly cloud-filtered data

All examples are from night ocean data.

The extension to day ocean is straight forward.

The extension to day and night land data is more complicated.

Cloud contamination is detected using three predictors of spectral gradients, corrected for water continuum absorption.



d34 d23 d12

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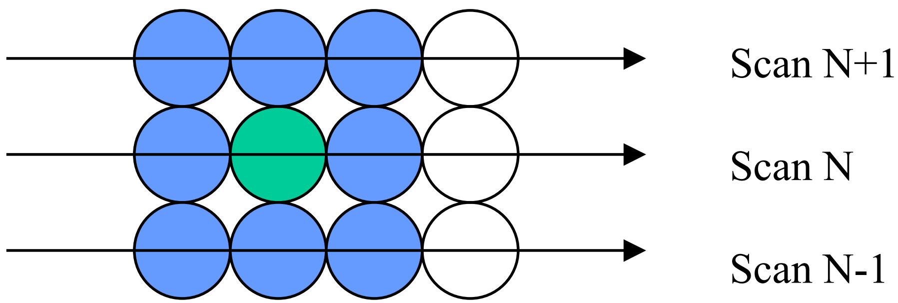
The 3x3 spatial coherence test serves as the first cloud filter.
If the data are already cloud-cleared, this test is not used..



The spatial coherence (SC) test uses a 3 x 3 pattern of nine AIRS footprints.
SC is tested at 2616cm-1 (#2333) and 1231cm-1(#1291) resulting in
sc4=max(bt2616)-min(bt2616) and sc8=max(bt1231)-min(bt1231).
The center footprints passes the SC test if sc4<0.5K and sc8<0.5K.

NEDT(2616) and NEDT(1231) is 0.07K for 300K scenes.

Residual cloud contamination at 2616cm-1 E ~ (sc4 - 3*NEDT)/3

Normally we use sc4=0.5K and NEDT(2616cm-1, 300K) = 0.07 K, E ~ 0.1 K
for the following we use sc4=0.7K and 1K to illustrate cloud screening

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The first order metric of the degree of cloud contamination is the outlier ratio. An outlier is defined as a footprint with a derived sea surface skin temperature which differs from the sst analysis by more than 3K

Data with outlier ratios of 1 outlier per 100 points are OK.

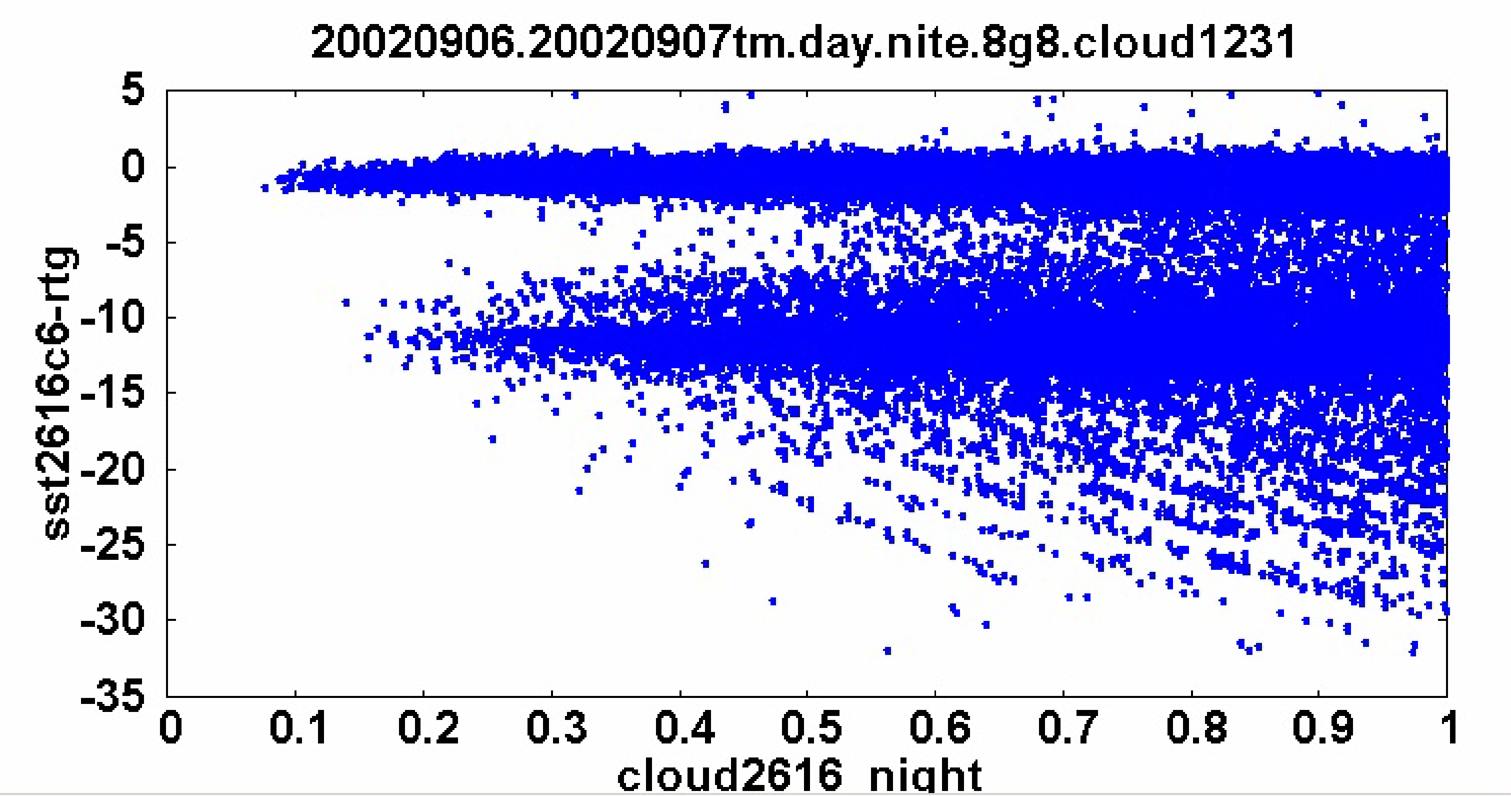
We use the NCEP Real Time Global SST (RTG.SST)

Based on a year of testing, the estimated RTG.SST outlier ratio is better than 1:5000 for night ocean between 50 degree latitude.

We use the 2616cm-1 and 1231cm-1 derived sst during day/night, respecively

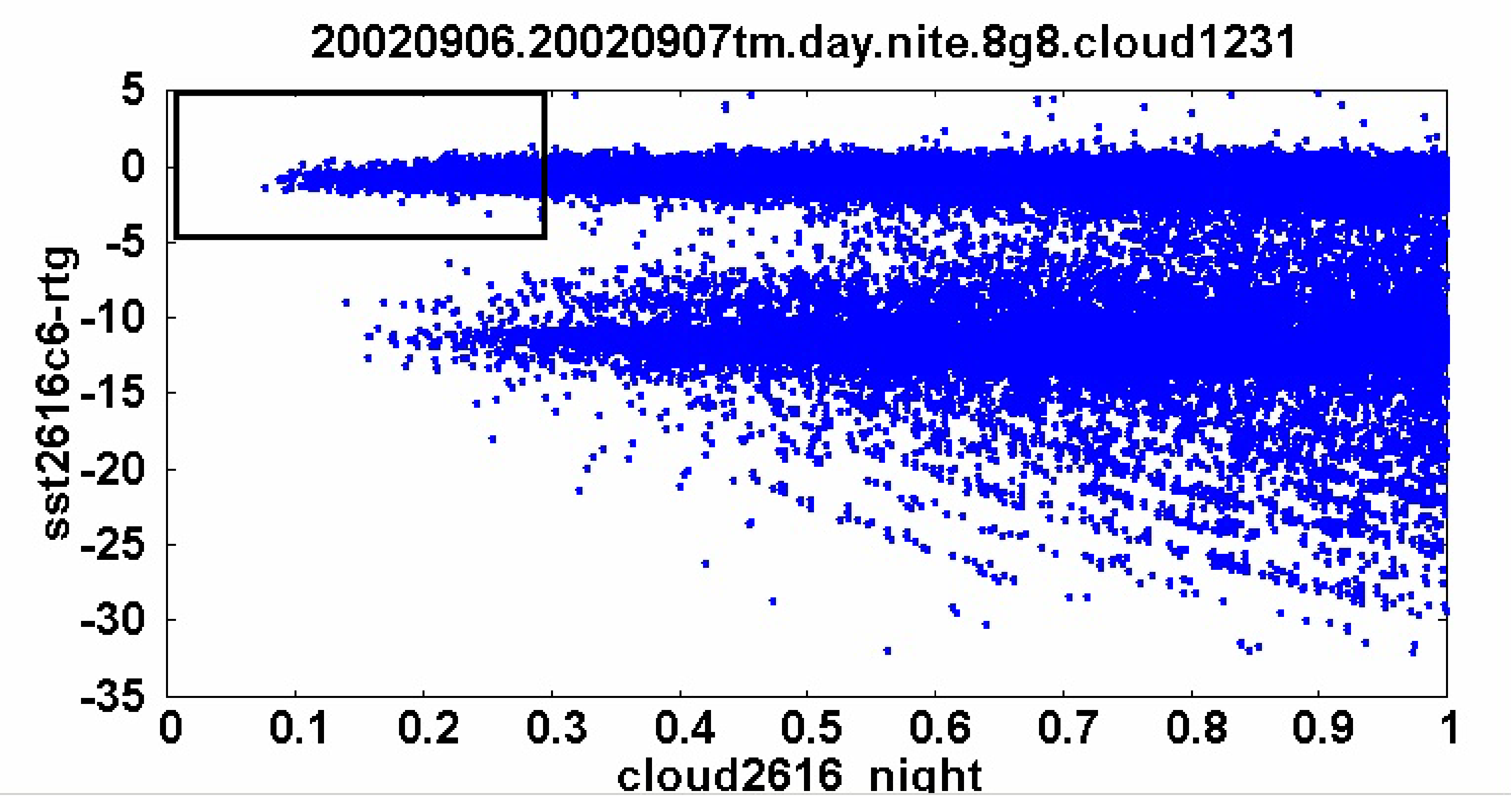
SST or SST climatology are not part of the cloud filter

The spatial coherence filter alone produces unacceptable results at any reasonable threshold



There are 450,000 ocean night footprints between +/- 50 degree latitude.
The spatial coherence filter alone passes 53647 footprints as “clear”, but 17009 are >3K rtg.sst outliers

An sst based threshold produces clean spectra but very low yield



The spatial coherence filter alone passes
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Data which pass the SC test are screened by additional test.

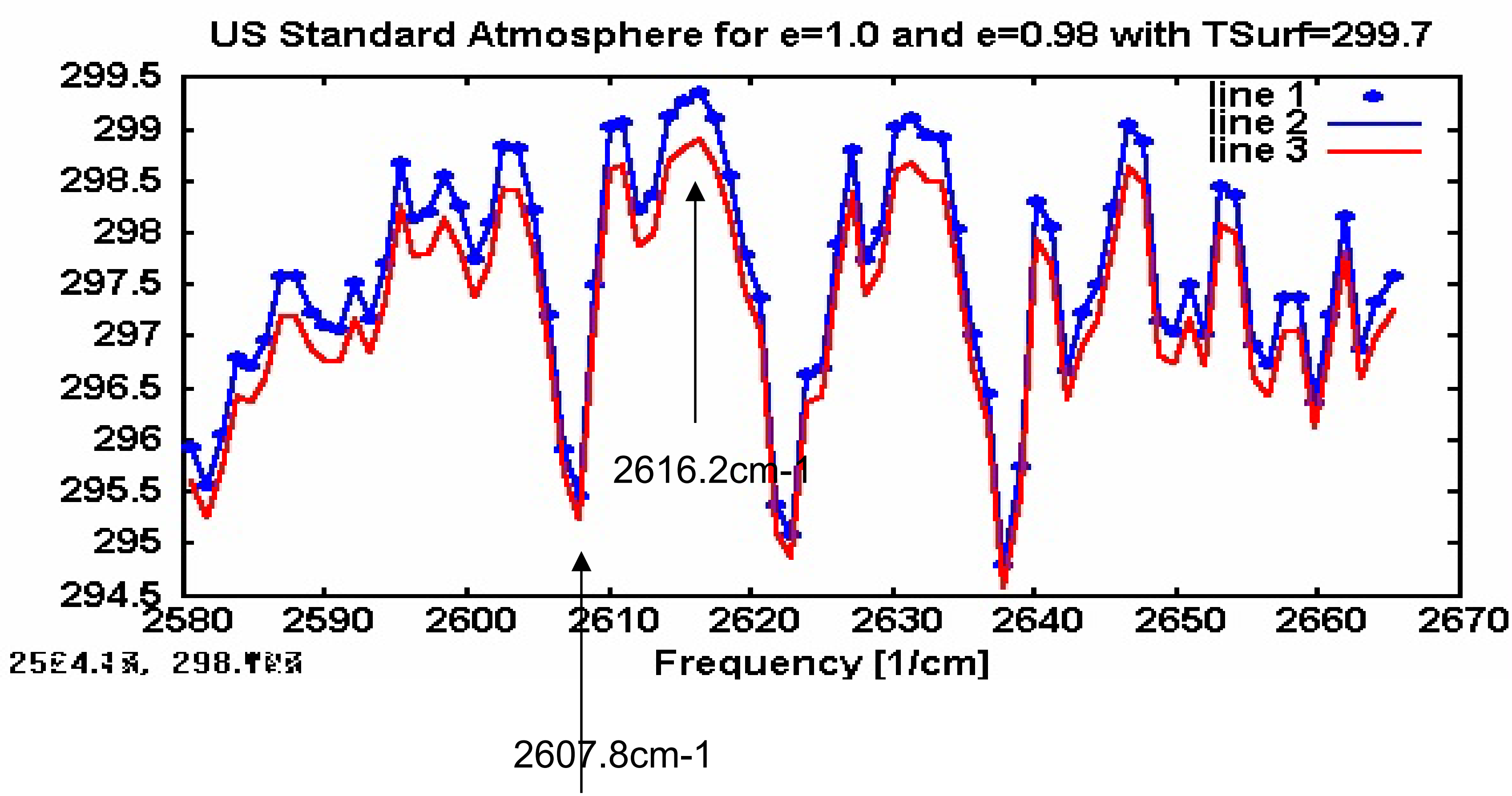
The selection of the additional test and filter thresholds has to be carefully matched to the task to be accomplish and in what part of the spectrum.

Too little filtering permits cloud contamination, to much filtering eliminates good data.

For night ocean data the low stratus test (q2) is the minimum

The q2 test makes use of the fact that weak lower tropospheric water lines which are normally seen in absorption above the warm surface, disappear, or appear in emission.

The 2607.8 cm-1 channel is sensitive to water in the lower troposphere. This make the channel very useful to detect low cirrus.



if (bt2616-bt2607)<0.5K then the data is probably contaminated with low cirrus

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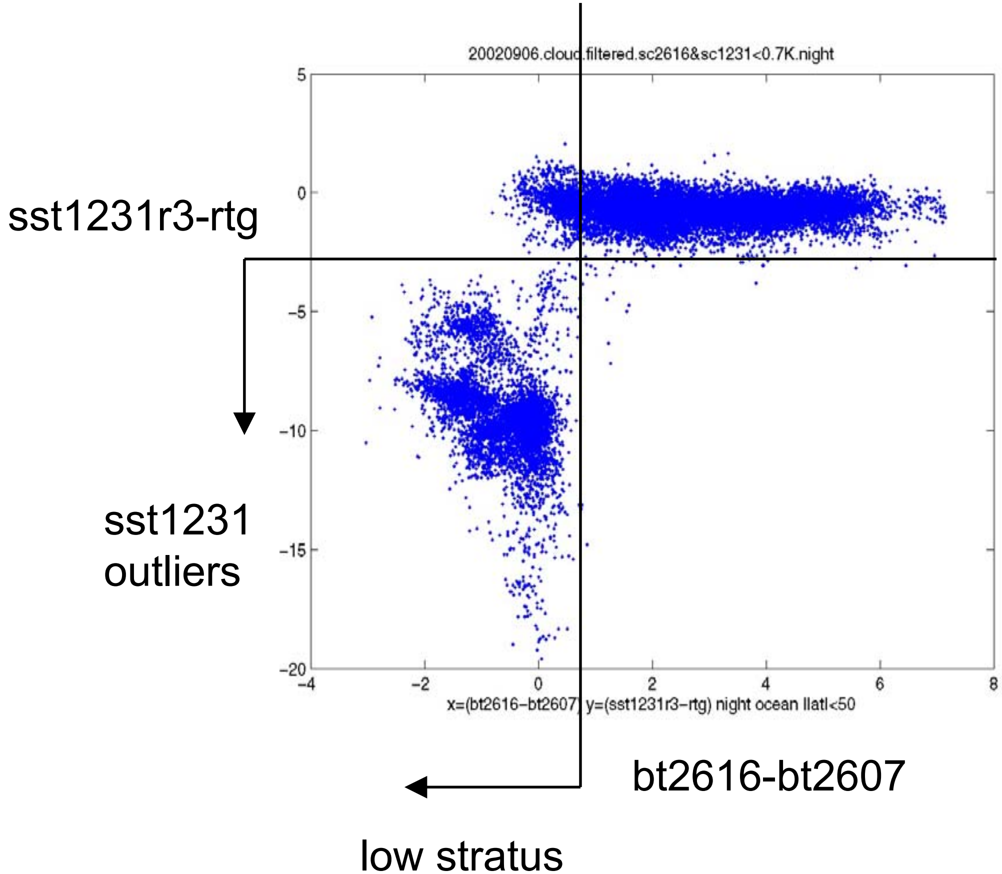
Low Stratus Cloud Test

The LSC test uses the fact that the weak waterline at 2607cm-1(#2325), which typically is seen in absorption relative to bt2610 (#2327), is very shallow or even inverted.



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The spatial coherence filter alone passes
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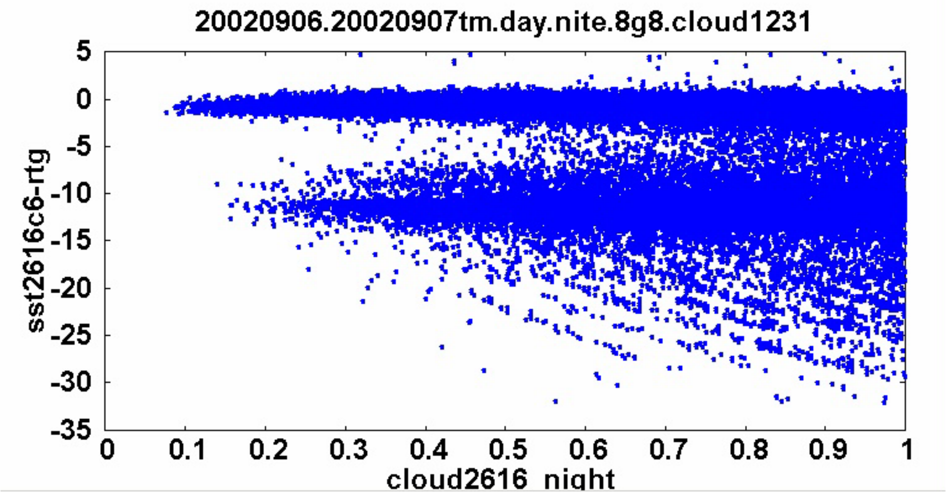
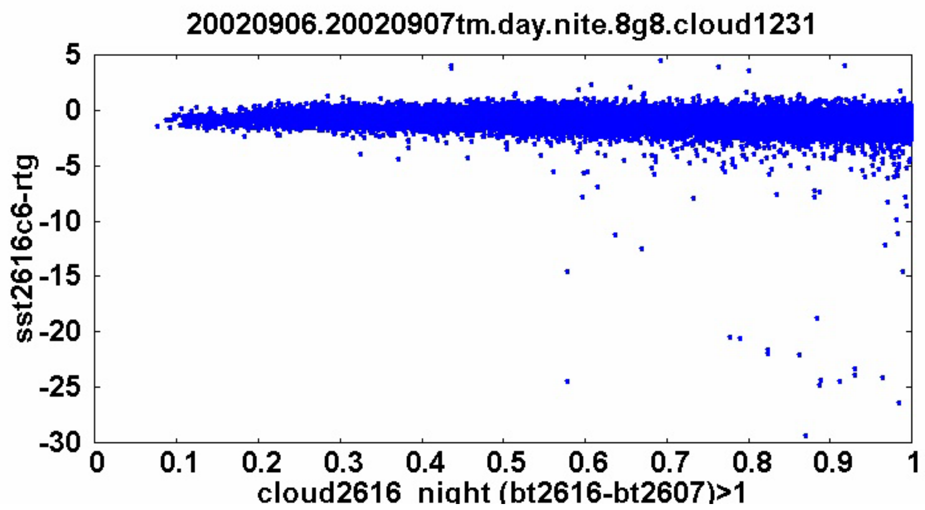


Spatial coherence filter only
17009 outliers in 53647 points

1:3 outliers



Coherence filter followed by
low stratus filter
116 outliers in 29176

1:251 outliers

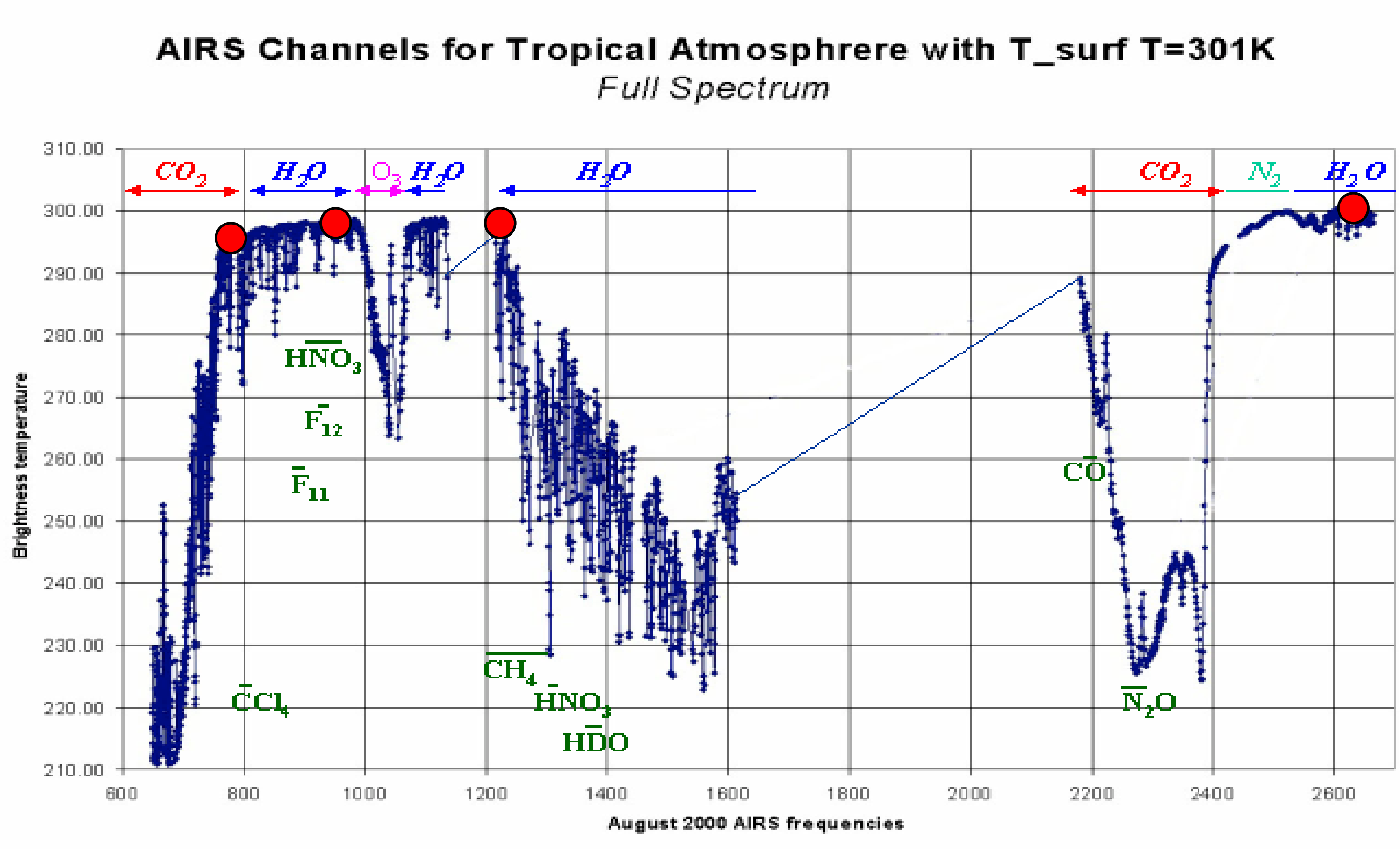
The emissivity effects at 2616 and 1231 are relatively minimal. This means that no further tests are needed for 2616cm-1 or 1231cm-1 based sst measurements.

The spectra may be contaminated by cirrus and/or dust.

The d23 and d34 filters test for cirrus and/or dust contamination over ocean.

Emissivity retrievals over land from data which are cirrus or dust contaminated will produce spurious results.

Cloud contamination is detected using three predictors of spectral gradients, corrected for water continuum absorption.



d34 d23 d12

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For the additional screening of the cloud-filtered data we use

1. d12=(observed-predicted (bt2616-bt1231) (with day/night offset)
   cloud contamination

2. d23=(observed-predicted) (bt1231-bt943)
   dust and cirrus contamination

3. d34=(observed-predicted)(bt943-bt790)
   cirrus contamination

Test 2. is similar to the (observed-calculated.ECMWF)(bt1232-bt961) used by L. Strow. The combination of the results of Test 2 and Test 3. may allow discrimination between cirrus and silicate dust.

Next we discuss Test 1.

Test 1. (observed-predicted) (bt2616-bt1231)

This test is very effective because of the Planck function leverage between 1231cm-1 and 2616cm-1

Cloud fraction	cloud top DeltaT	night bt2616 - bt1231.water.corrected	day
5%	20K	0.2K	1.1K
5%	40K	0.5K	1.4K
10%	20K	0.4K	1.3K

Raw (bt2616-bt1231) = 2.1 +/-0.97 1%tile=0.8K 99%tile=5K water sensitive

If we can predict (bt2616-bt1231) at the 0.2K level, then many clouds can be eliminated using a single footprint spectrum

predict(bt2616-bt1231) is empirically trained on extremely carefully cloud-filtered and cirrus screened AIRS 200212.night data.

d12 can be predicted with 0.2K rms (night)

Test 1. (observed-predicted) (bt2616-bt1231)
AIRS 2003 May night ocean data

night version uses q2=bt2616-bt2607

(bt2616-bt1231)pred. = 0.78013*q2-0.11912+0.11276/cos(sza)

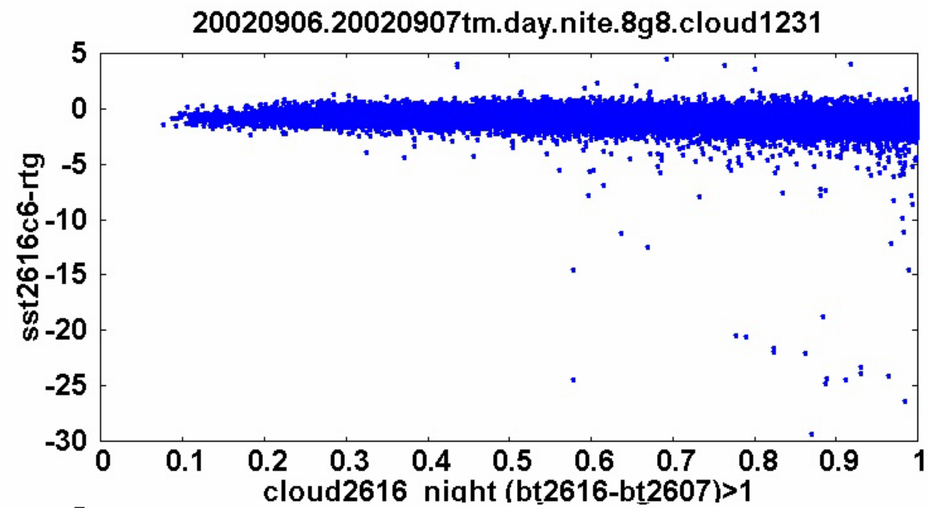
(Obs-predict) bias = 0.02K rms=0.2K

day/night version uses q1=bt1231-bt1228

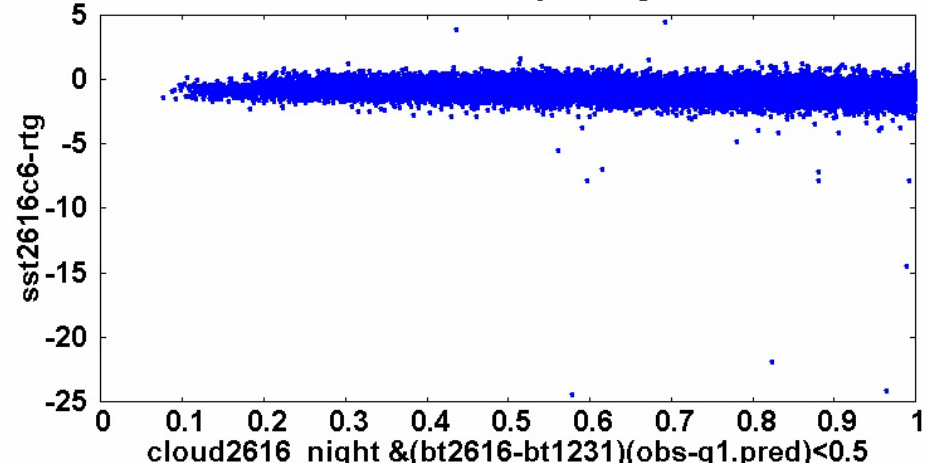
(bt2616-bt1231).pred=2.71399.*q1-1.19765-1.30062/cos(sza)

(obs-pred) bias = 0.02K rms= 0.28K at night
0.8K rms= 1.6K (day due to glints)

(observed-predicted) (bt2616-bt1231) (slope in window channels)



1:250 outliers



less than 1:1000 outliers

If we require (obs-pred)(bt2616-bt1231)<0.5K
55 sst2616-rtg > 2K outliers in 23821 points
22 > 3K

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Prescriptions for day/night filters of cloud-filtered spectra:

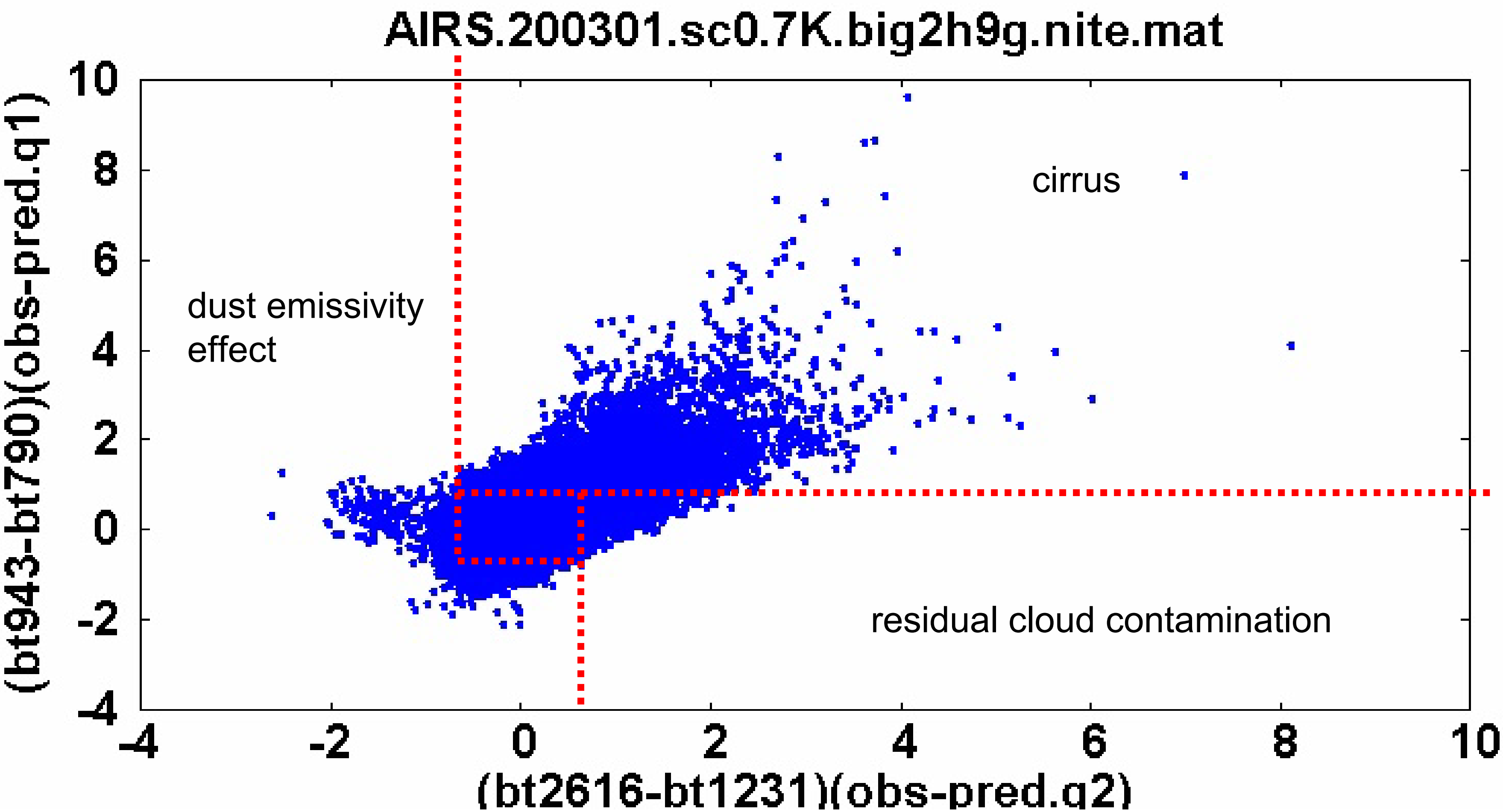
d34=(bt943-bt790)-(-0.32127+2.37127.*q1-1.09312./cos(sza))

d23=(bt1231-bt943)-(-0.41007+0.46492.*q1-0.81877./cos(sza))

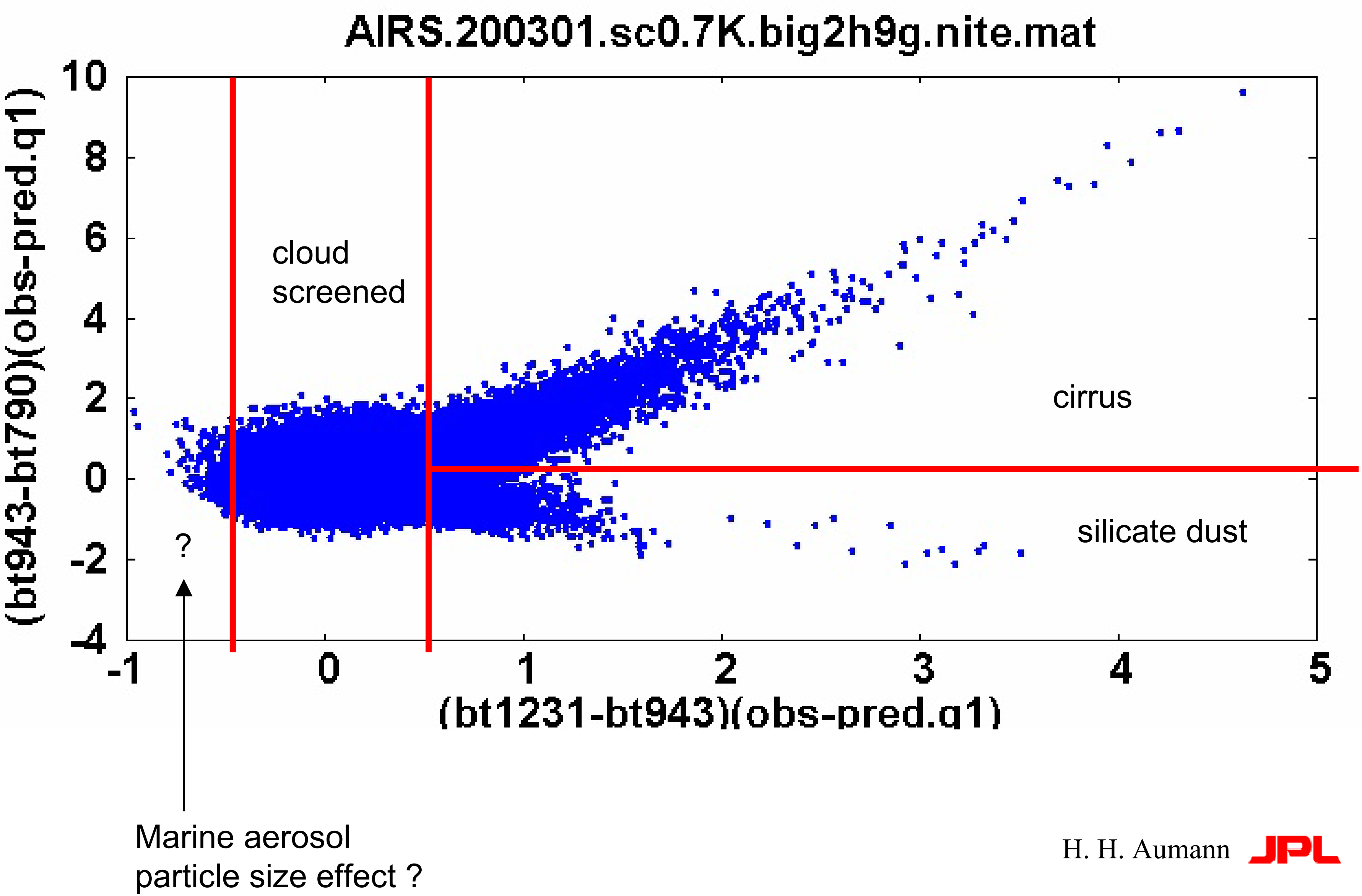
d21=(bt2616-bt1231)-(-1.19765+2.71399.*q1-1.30063./cos(sza))

q1=(bt1231-bt1228) (#1291-#1285)

The d12 d34 diagram separates cold clouds from cirrus,and dust contamination



The d23 d34 diagram separates cirrus,and silicate dust contamination



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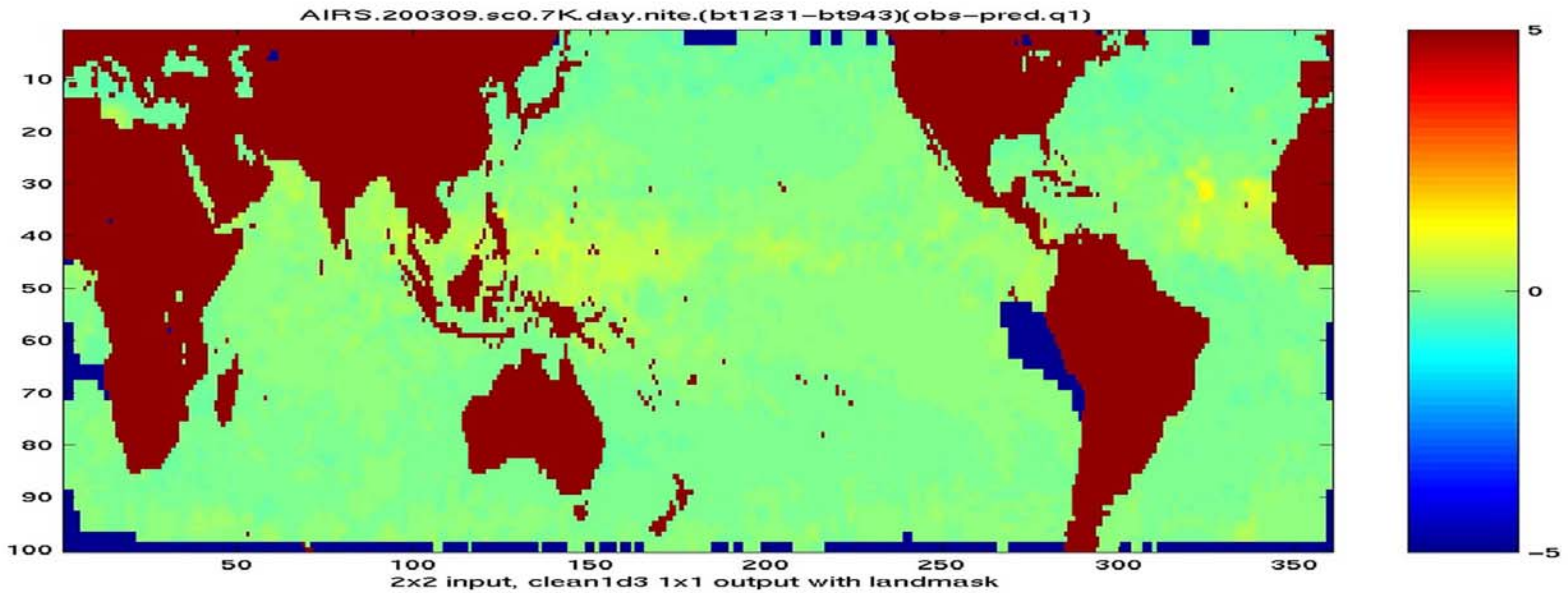
d23 shows interesting time and space correlated effects



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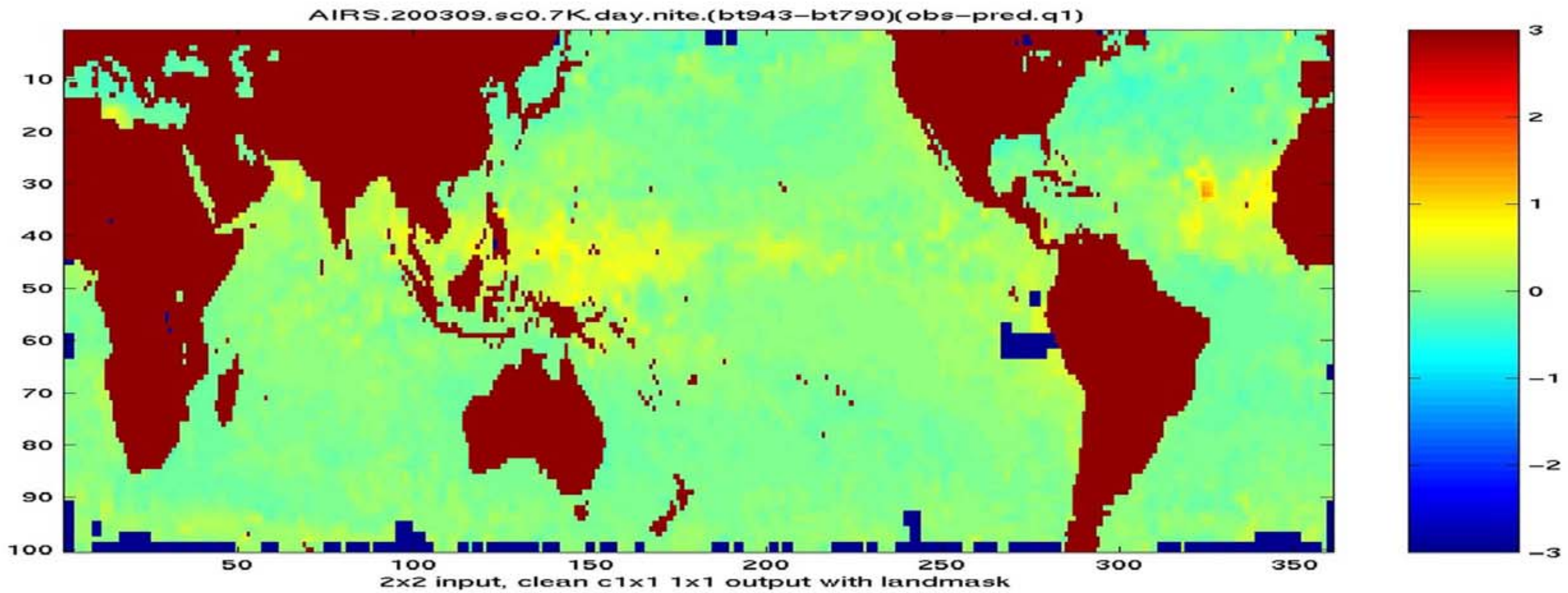
d34 shows interesting time space correlated effect.
Combining d23 and d34 indicates that the material coming off the coast of Africa appears in July 2003 is not silicate dust.



Conclusions:

Spatial coherence cloud-filtered AIRS spectra are contaminated by residual cloud, cirrus, dust and aerosol effects.

These effects are much larger than the 0.1K required for global minor gas retrievals.

Residual cloud, cirrus, aerosols and dust produce spectrally correlated effects which decrease the brightness temperature of the spectrum and which do not average to zero.

Screening the spectra with the (bt2616-bt2607) and (bt2616-bt1231) filters eliminates a large fraction of cloud contamination

Additional filters are available, such as the bt1231-bt943 and (bt943-bt790) for more critical screening and diagnostics.

The same filters can be use to screen cloud-cleared radiances and for single footprint cloud-filtering

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